Trends in Canadian air pollutant emissions from human activities: 1990 to 2018

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Objectives

The government of Canada estimates that air pollution is linked to over 14,000 premature deaths per year in Canada (Health Canada, 2020). Through observing regional trends in Canadian air pollutant emissions and analyzing the causes related to human activities within those regions, this project aims to provide useful insights that can be utilized to reduce pollutant emissions.

We expect that each province contributes different types of air pollutant emissions depending on the primary industries in the region. A thorough analysis of the dataset at the provincial level will provide detailed reports of the human activities that are mainly causing air pollution.

In order to address the problems such as what are the generic trends of the pollutants across Canada, and what would be the correlations between them, we first conducted a nationwide analysis. Since it is expected to observe different pollutant activities depending on the main industries within the provinces, we then selected five major provinces with the greatest air pollutant contributions to examine in depth to determine the sources of those pollutants. To obtain more information about the human activities involved within the sources, the sectors and subsectors of the activities contributing to the pollution are inspected. Finally, we provided basic suggestions and interpretations of possible reasons for changes in the trends and what could be done to improve the environment.

Data preparation

Data were obtained from Canada's Air Pollutant Emissions Inventory (**APEI**) through the Canadian open data portal (Government of Canada, 2020), as a CSV file. The dataset contained emissions data collected from 1990 to 2018 for 18 air pollutants (Supp. Tbl. 1, see Appendix), organized by year, region (13 provinces/territories), source (11 categories of human activities responsible for emissions), sector and subsector (sub-categories of human activities, breaking down emissions in more detail under each source category).

The quality of the dataset was hindered by the fact that its categorical columns appeared to be geared toward use in the Excel user interface. Specifically, some of the levels under the region and source categories contained aggregated totals combining all regions or all sources. In addition, the dataset contained aggregated totals for each source, as well as non-aggregated values for sector/subsector contributions within each source. This posed a challenge in terms of data tidiness (multiple data types: totals and non-totals). Using the Pandas library, we addressed this by:

1. Removing rows containing aggregated totals of all regions (listed as "CA" for Canada) or all sources (listed as "GRAND TOTAL"). In addition, we removed rows where the region was listed as "Unspecified", to focus on differences between specific regions.
2. Splitting the remaining data into two analytical streams:
    a. Analyzing source-level totals (where sector and subsector categories were null) for each pollutant by region and year, to understand the overarching human activities contributing to air pollutant emissions trends.
    b. Analyzing data organized by sector or subsector within a given source, to understand the specific human activities encompassed by a source category and their individual contributions to air pollutant emissions trends.

The cleaned data still contained missing values, which we understood to stem from the fact that not all regions or human activities emit all pollutants in measurable quantities. Therefore, we chose to ignore missing values in all further analyses.

Analysis

Canadian air pollutant emissions overall trends 1990-2018

To understand the overall trends in air pollutant emissions in Canada, we analyzed the total emissions of each pollutant per year, combining all regions and human activity sources (Fig. 1). For most pollutants, positive autocorrelation was observed for lag periods of 1-5 years, suggesting that trends in emissions levels tended to continue over several years (Supp. Fig. 1, see Appendix). Pollutants with an overall increasing trend from 1990 to 2018 included total particulate matter (**TPM**, which includes particles up to 100 microns in diameter), particulate matter under 10 microns (**PM_{10}**), and ammonia (**NH_3**), although NH_3 emissions had stabilized from the mid-1990s onward. Also of concern was the trend seen in emissions of particulate matter under 2.5 microns (**$PM_{2.5}$**), which began to increase sharply in the mid-2000s. The remaining pollutants showed an overall decrease from 1990-2018.

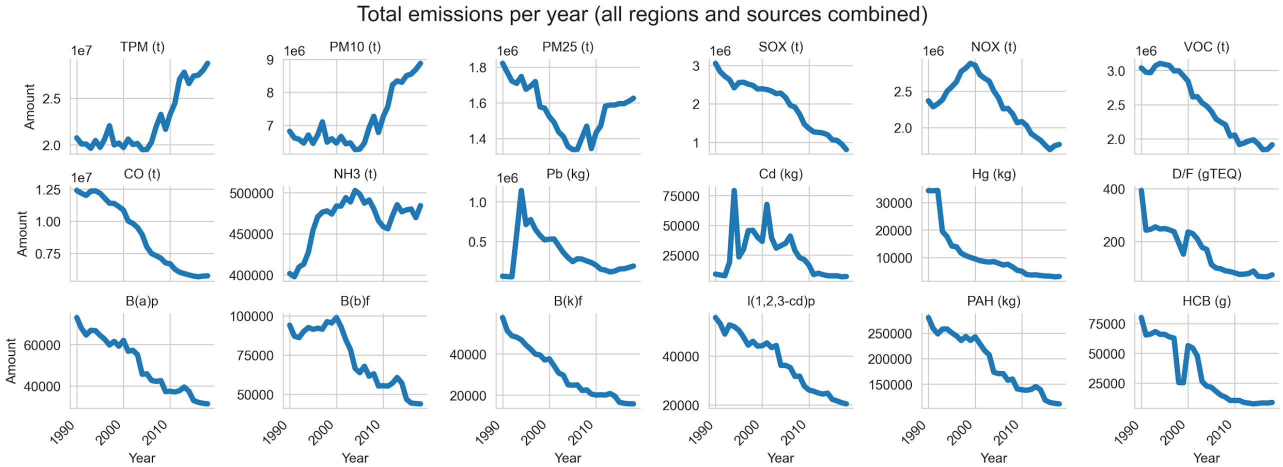

Figure 1. Sum total of pollutant emissions per year for all Canadian regions and all human activity sources combined.

Examining the median and distribution of pollutant emissions in 5-year increments (Fig. 2), there was high variance and many outliers at the high end of the range for most pollutants (high kurtosis). We speculated that region-specific and/or human activity source-specific outliers could be making outsized contributions to total pollutant emissions levels. Therefore, we investigated regional and human activity source-specific contributions to pollutant emissions in the bulk of the remainder of this analysis.

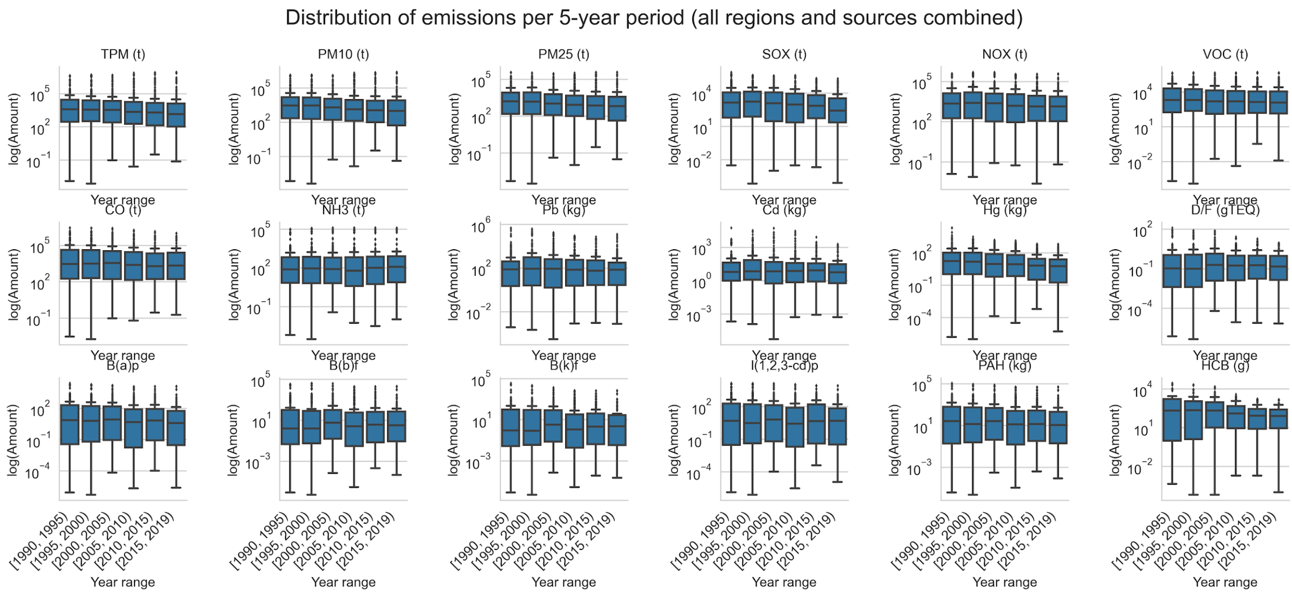

Figure 2. Box-and-whisker plots of pollutant emissions per 5-year period for all Canadian regions and all human activity sources combined.

Correlation analysis of Canadian air pollutant emissions

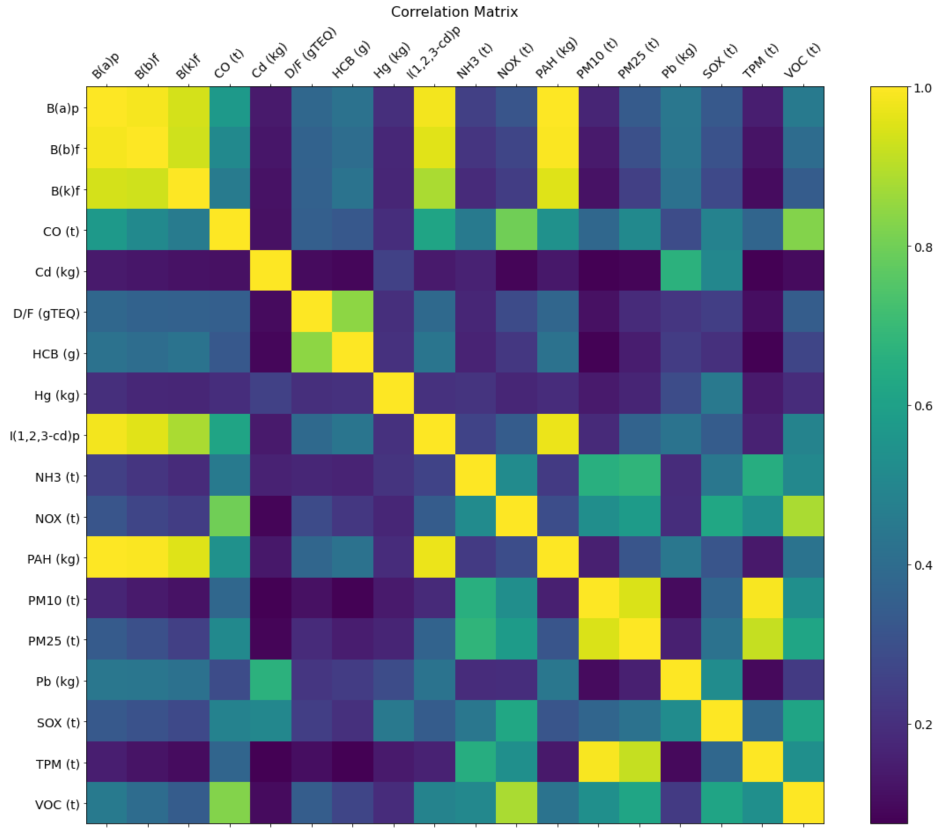

Figure 3. Correlation matrix of all air pollutants, Canada-wide.

We created a Correlation Matrix of the pollutants present in the dataset, to investigate for trends in pollutants which co-occur at higher rates. The pollutants with the highest correlation coefficient include the **Benzo(a)pyrene**, **Benzo(b)fluoranthene**, and **Benzo(k)fluoranthene** (the sum of which is seen in **Polycyclic aromatic hydrocarbon**, or PAH), at a >= 0.8 correlation coefficient with **Indeno(1,2,3-CD)pyrene**. These pollutants are linked to Aluminum Industry and Home Firewood Burning in the province of Quebec (see case studies below).

Carbon monoxide (CO) also has a correlation coefficient grouping of about 0.8 with **Nitrous oxides** (NO_x) and **Volatile organic compounds** (VOCs). NO_x and VOCs are both correlated with Oil and Gas Industry in Alberta, and Transportation and Mobile Equipment in Ontario (see case studies below).

Finally, **Total particulate matter** (TPM) and it's constituent pollutants, **PM10**, and **PM2.5,** are also strongly correlated with each other, with a near-1.0 coefficient. Particulate matter is associated with Oil and Gas Industries in Alberta and Saskatchewan, as well as Agriculture Industries, and Dust from Unpaved Roads and Construction Operations in both provinces (see case studies below). These correlations between pollutants and industries do not necessarily mean that they are arising from the same sources, however, as correlation does not imply causation.

Regional contributions to air pollutant emissions

To understand the high variance and kurtosis in the APEI data (Fig. 2), we examined air pollutant emissions trends by region (Fig. 4). Several provinces emerged as top polluters for one or more air pollutants: Alberta (**AB**), Saskatchewan (**SK**), Manitoba (**MB**), Ontario (**ON**), Quebec (**QC**). While most provinces had succeeded in reducing their top pollutant emissions from 1990 to 2018, Alberta and Saskatchewan stood out for their substantial increases in particulate matter (particularly TPM and PM_{10}) and NH_3 emissions. We further investigated the human activities responsible for the top pollutant emissions in these five provinces in the case studies below.

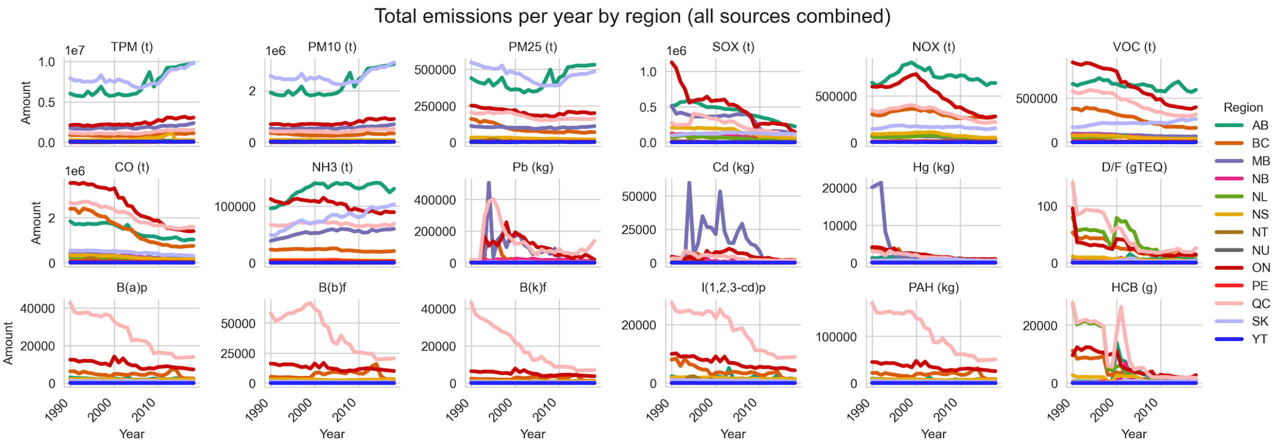

Figure 4. Sum total of pollutant emissions per year by region, for all human activity sources combined.

Case study: Saskatchewan

Saskatchewan is among the top contributing Canadian regions for all particulate matter (TPM, PM_{10}, and $PM_{2.5}$) and NH_3. Emissions of TPM, PM_{10}, and NH_3 have increased from 1990 to 2018, and $PM_{2.5}$ emissions have begun to increase in the past decade. In addition, Saskatchewan is the only region in Canada where VOC emissions have increased during this time period (Fig. 4).

Sources contributing to key pollutants of interest in Saskatchewan

To understand the human causes of Saskatchewan's air pollution trends, we analyzed the human activities contributing emissions of key pollutants in Saskatchewan. The main sources contributing to particulate matter were *Agriculture* (decreasing trend) and *Dust* (increasing trend). For VOC, the *Oil and Gas Industry* (increasing trend) was the primary contributor. For NH_3, *Agriculture* (increasing trend) was the main contributor (Fig. 5).

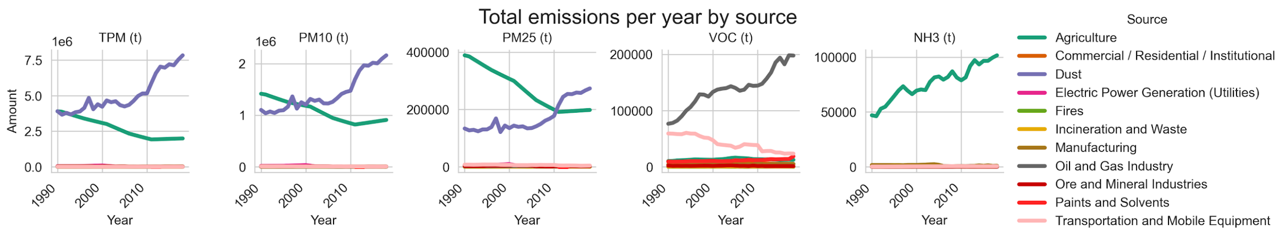

Figure 5. Sources contributing to key air pollutant emissions in Saskatchewan.

Agriculture sectors contributing to particulate matter and NH_3 pollution

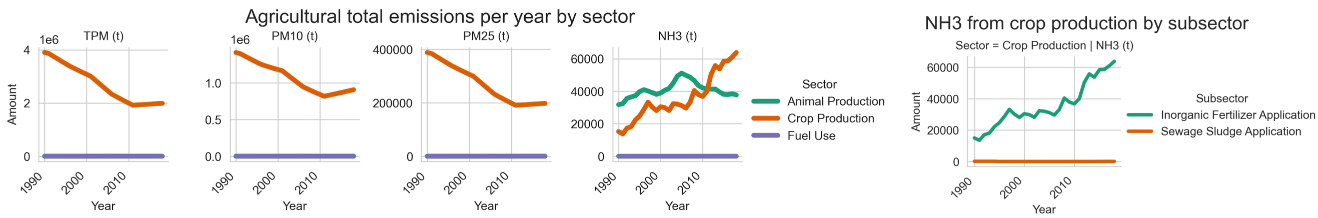

Figure 6. left: Agricultural sectors contributing to particulate matter and NH_3 emissions in Saskatchewan. *right:* Crop Production subsectors contributing to rising NH_3 emissions in Saskatchewan.

Within agricultural pollution, *Animal Production* contributed heavily to NH_3 emissions (increasing trend to the mid-2000's, decreasing trend thereafter). *Crop Production* contributed to both particulate matter (decreasing trend) and NH_3 (increasing trend) emissions (Fig. 6, left). The main *Crop Production* subsector driving to increasing NH_3 emissions was *Inorganic Fertilizer Application* (Fig. 6, right). Overall, the most concerning trend in *Agriculture* was the rapidly increasing emissions of NH_3 due to *Inorganic Fertilizer Application* in the

Crop Production sector. It may be prudent for the federal or provincial government to impose stricter regulation of crop production practices to limit NH_3 emissions.

Dust sectors contributing to particulate matter pollution

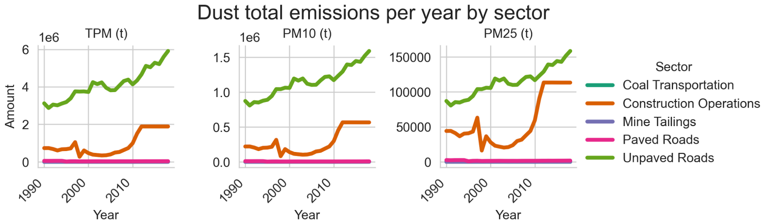

Figure 7. Dust sectors contributing to particulate matter emissions in Saskatchewan.

Within *Dust* pollution, transportation activity on *Unpaved Roads* (increasing trend) and *Construction Operations* (increasing trendin the mid-2000's to mid-2010's) were the primary contributors to particulate matter pollution (Fig. 7). Overall, the most concerning trend in *Dust* emissions was the increasing particulate matter pollution from *Unpaved Roads*. As *Paved Roads* did not contribute significantly to *Dust* pollution, it may be beneficial to promote road paving, although the overall environmental impact of road paving (beyond its effect on particulate matter emissions) would first need to be assessed.

Oil and Gas Industry sectors contributing to VOC pollution

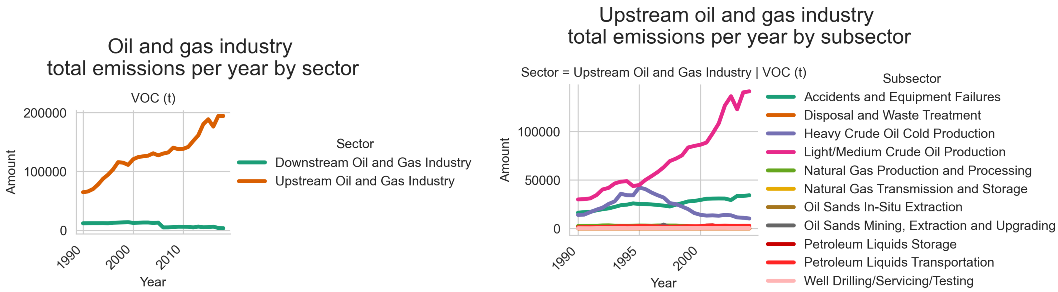

Figure 8. left: Oil and Gas Industry sectors contributing to VOC emissions in Saskatchewan. *right:* Upstream Oil and Gas Industry subsectors contributing to VOC emissions in Saskatchewan.

The *Upstream Oil and Gas Industry* was the primary contributor to VOC pollution (increasing trend; Fig. 8, left). The main subsector of the *Upstream Oil and Gas Industry* driving this trend was *Light/Medium Crude Oil Production* (Fig. 8, right). Overall, the most concerning trend in the *Oil and Gas Industry* was the rapidly increasing emission of VOC by *Light/Medium Crude Oil Production*. It may be prudent for the federal or provincial government to impose stricter regulation on this subsector of the oil and gas industry.

Case Study: Alberta

Like Saskatchewan, Alberta contributes heavily to particulate matter in the form of **TPM**, **$PM_{2.5}$**, and **PM_{10}.** It is also a heavy Canadian contributor to output of **NH_3**, **NOx**, **SOx**, and **VOCs**. Particulate matter emissions have generally increased since 1990, while NH_3 and VOC emissions have been fairly level since the mid-1990s. SOx and NOx have decreased somewhat since the mid-1990s.

Sources contributing to key pollutants of interest in AB

The main sources contributing to particulate matter were *Dust* (increasing trend) and *Agriculture* (increasing trend). For SOx, NOx, and VOCs, the *Oil and Gas Industry* were the primary contributors, with NOx and VOCs on a level-to-increasing trend. *Agriculture* was the primary source of NH_3 emissions, which increased between 1990 and 2000, and have remained fairly steady up to 2018.

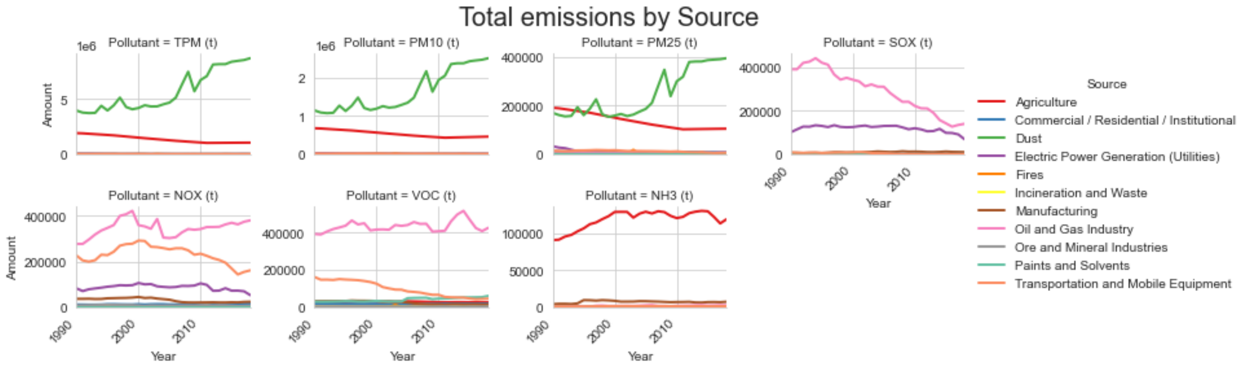

Figure 9. Sources contributing to key air pollutant emissions in Alberta.

Agriculture sectors contributing to emissions

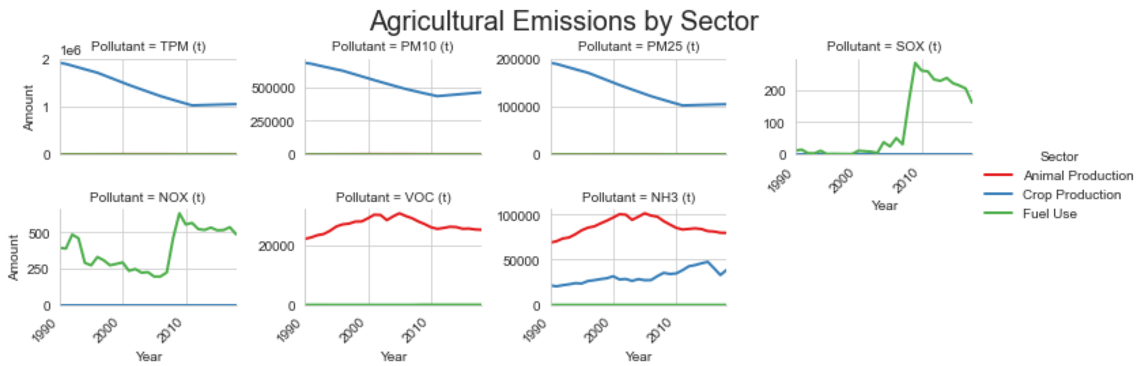

Figure 10. Agricultural sectors contributing to pollutant emissions in Alberta

Crop Production has been a significant source of particulate matter (decreasing up to 2010, level thereafter) and NH_3 (increasing trend). *Fuel Use* has contributed to a sharp increase in both NOx and SOx emissions beginning in the late 2000s, after which period that has been a slight decline. *Animal Production* has been a fairly steady contributor to both VOCs and NH_3.

Dust sectors contributing to particulate matter emissions

Transportation activity on *Construction Operations* and on *Unpaved Roads* are the primary contributors to all particulate matter pollution generated in the province of Alberta. Construction operations saw a sharp uptick in the mid-2000s, while unpaved roads have had a more steady trajectory.

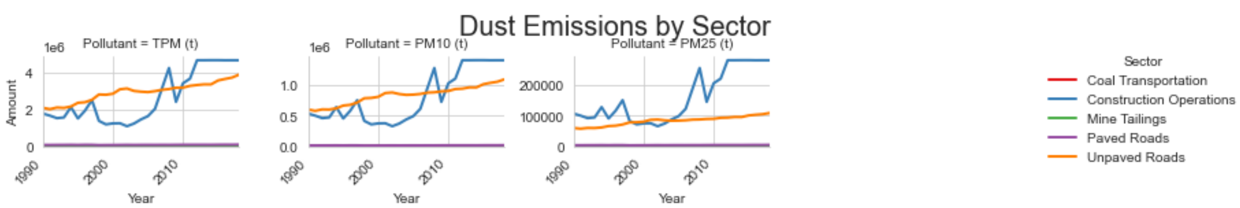

Figure 11. Dust sectors contributing to particulate matter emissions in AB.

Oil and gas industry subsectors

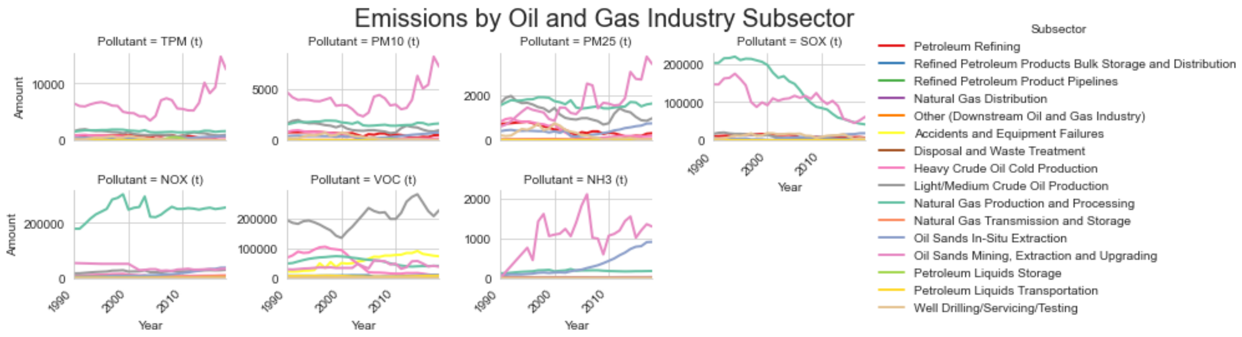

Figure 12. Oil and gas industry sectors contributing to emissions in AB

Upstream Oil and Gas is the primary source of all emissions in the *Oil and Gas Sector* for Alberta. *Oil Sands Mining, Extraction, and Upgrading* has contributed the most as a subsector to particulate matter (increasing trend) and NH_3 (irregular trend). *Natural Gas Production and Processing* has also been a significant source of $PM_{2.5}$ (steady trend), SOx (decreasing trend) and NOx (steady trend). *Light/Medium Crude Oil Production* has been a key contributor of VOCs, with an irregular trend.

Transportation and mobile equipment sectors

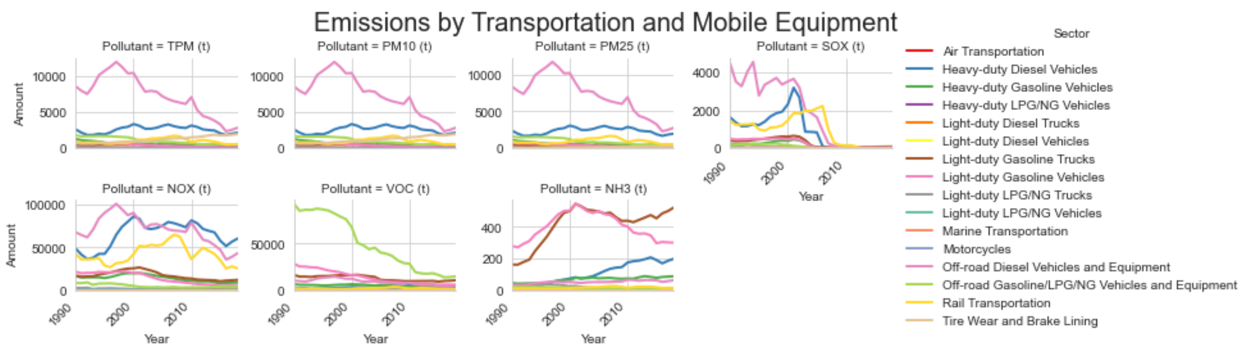

Figure 13. Transportation almond mobile equipment sectors contributions to emissions

Off-road Diesel Vehicles and Equipment accounted for the highest volumes of particulate matter, SOx, and NOx through the mid-2000s. The sector has decreased annual emissions of these pollutants since then. *Off-road Gasoline/LPG/NG Vehicles and Equipment* have historically accounted for high volumes of VOC emissions, but have reduced emissions since 1990 by about 75%. *Tire Wear and Brake Lining*, and *Light Duty Gasoline Trucks* account for high ammonia emissions. The former has been on a steady decline since around 2000, while *Gasoline Trucks* are trending upwards.

Case Study: Ontario

Examining the plot for the different regions (Figure 4), we can determine that the total particulate matter (TPM) and PM10 showed an increase from the 1990s to 2018 in Ontario. Interestingly, total PM25 levels in Ontario declined drastically from the 1990s to 2010. However, from 2010-2018 the PM25 levels started increasing in Ontario, which contributes to the overall increase in TPM observed.

We chose to do further inspection on the particulate matter pollutants (TPM, PM10, PM2.5), due to their continuous increase. Examining the numerical values, we see a TPM value of 2,121,534 tonnes (t) in 1990, which then increases to 3,054,924 t in 2018. Similar results are also seen for particulate matter 10 micrometers and under (PM10) for Ontario. Conversely, PM2.5 shows significant increases from 2008 to 2018, after exhibiting an overall decrease in PM2.5 levels beforehand. These elevated levels of PM2.5, combined with the increase in PM10 levels, contribute to the overall enhanced levels of TPM in Ontario shown in our plot. The next step was to create a plot that illustrates the total emissions by the different sources for each pollutant within Ontario.

Sources contributing to pollutants in ON

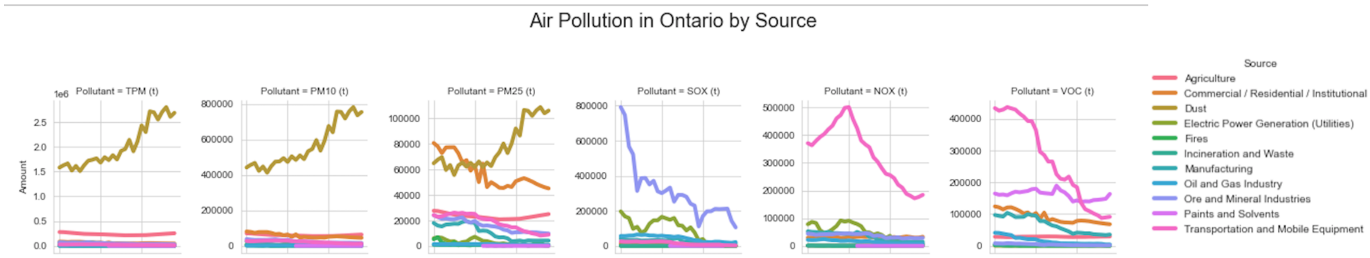

Figure 14: Ontario emissions sorted by the different sources for specific pollutants.

Examining the plot above, we can conclude *Dust* as the leading cause for the continuous increase in particulate matter (TPM, PM10 and PM2.5) in Ontario over the last 28 years. Agriculture and *Commercial/Residential/Institutional* sources were also major contributors to the increase in particulate matter in Ontario.

Dust sector top contributor to particulate matter emissions in ON

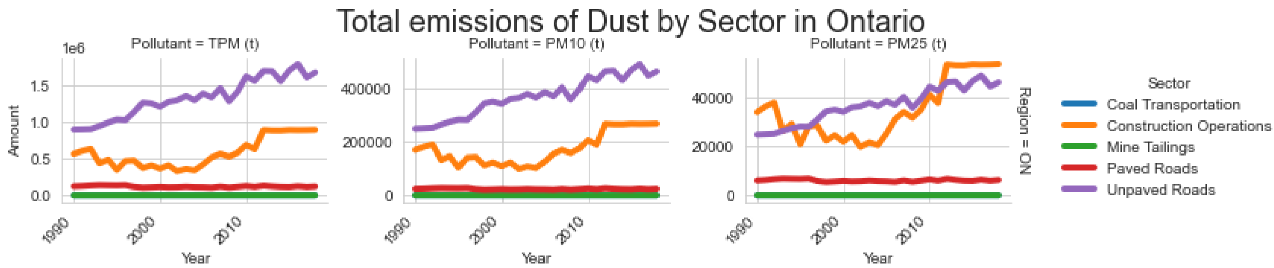

Figure 15: Dust emissions by the different sectors for Ontario.

Examining the plot above, we see *Unpaved Roads* and *Construction Operations* for the leading cause of dust pollution in Ontario. An increase in the number of vehicles on unpaved roads have contributed to a rise in tire dust present in the air. Tire dust is caused by friction between the tires of a vehicle and the road when contact is made, which leads to an increase in particulate matter pollution in the air (Government of Canada, 2018). Dust can also be caused by *Construction Operations* such as drilling/trimming activities, causing solid particles to become airborne, polluting the air as well (Toronto Environmental Alliance).

Commercial/Residential/Institutional sector particulate matter emissions in ON

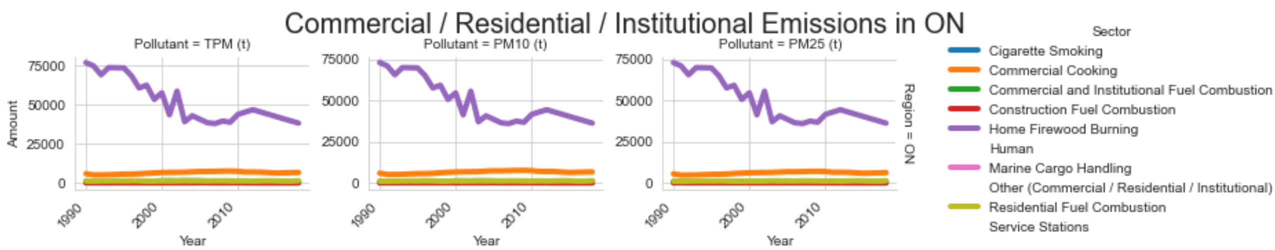

Figure 16: Commercial/Residential/Institutional emissions by the different sectors for Ontario.

The major contributors to *Commercial/Residential/Institutional* particulate matter pollution in Ontario is from wood combustion from fireplaces and wood stoves (Ministry of the Environment and Climate Change, 2015).

This form of particulate matter is especially common during the winter seasons in Ontario, where many households would be using their fireplaces for heat.

Overall by examining the air pollution in Ontario, it is evident that additional measures need to be placed to reduce the increasing levels of TPM, PM10 and PM2.5. Furthermore, failing to implement stricter guidelines for monitoring/reducing particulate matter pollution, can lead to future health implications for Ontario residents.

Although Ontario has shown an increase in total particulate matter pollutants over the last 28 years, overall, our plots indicate that Ontario has improved their recent efforts in reducing other air pollutants. Two prime examples of this are the decreases in NO_X and VOC. The Canada-United States Air Quality Agreement was signed in 1991, to examine and reduce air pollution (Government of Canada, 2018). The Ozone Annex, which was added in 2000, focused specifically on reducing both NO_X and VOC levels (Government of Canada, 2018). Examining our plot above, we are able to see the steady reduction in NO_X and VOC from 2000-2018. Specifically, Ontario has reduced the NO_X quality from approximately 599,000 t to 279,000 t in a span of 28 years. Similarly, VOC amounts have been reduced from approximately 903,000 t to 397,000 t during the same duration in Ontario, showing significant improvements.

Case Study: Quebec

From the regional trends (Fig. 4), Quebec appeared to be the primary region for the **PAH** pollutant emission during the 1990s. The four major PAH pollutants that are covered by the dataset are **B(a)p**, **B(b)f** , **B(k)f**, and **I(1,2,3-cd)p**.

As Quebec also showed noticeable changes and amounts for **CO**, **Pb**, **D/F**, and **HCB**, some of their insights are included as well.

Sources contributing to key pollutants of interest in Quebec

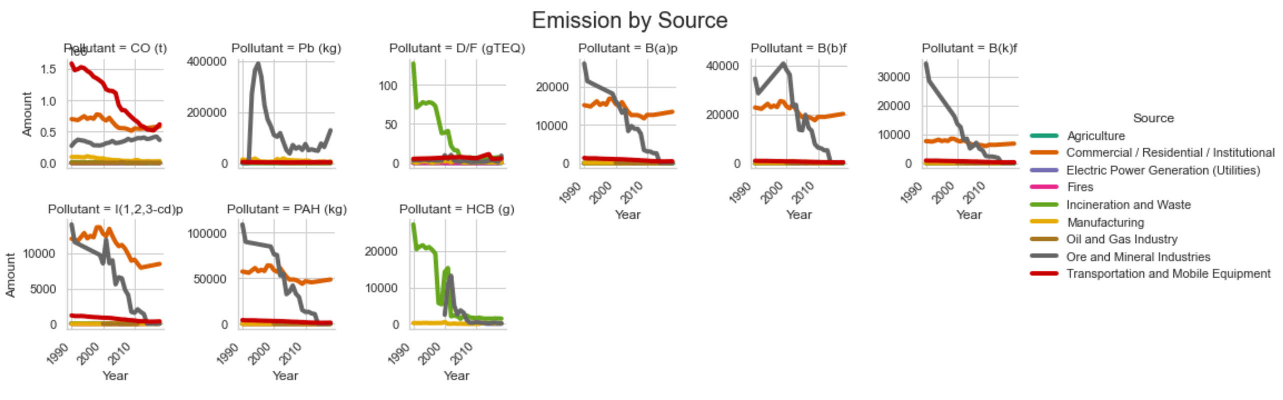

Figure 17. Sources contributing to key air pollutant emissions in Quebec.

Fig. 17 demonstrates that there are two major sources contributing to the PAH pollutant emission which are *Ore and Mineral Industries* and *Commercial / Residential / Institutional*. For *Ore and Mineral Industries*, the *Aluminum Industry* is found to be the primary reason *(Fig. 18)*.; whereas, for *Commercial / Residential / Institutional*, *Home Firewood Burning* is determined to be the major cause of the pollution (*Fig. 19*)

Sectors contributing to emissions

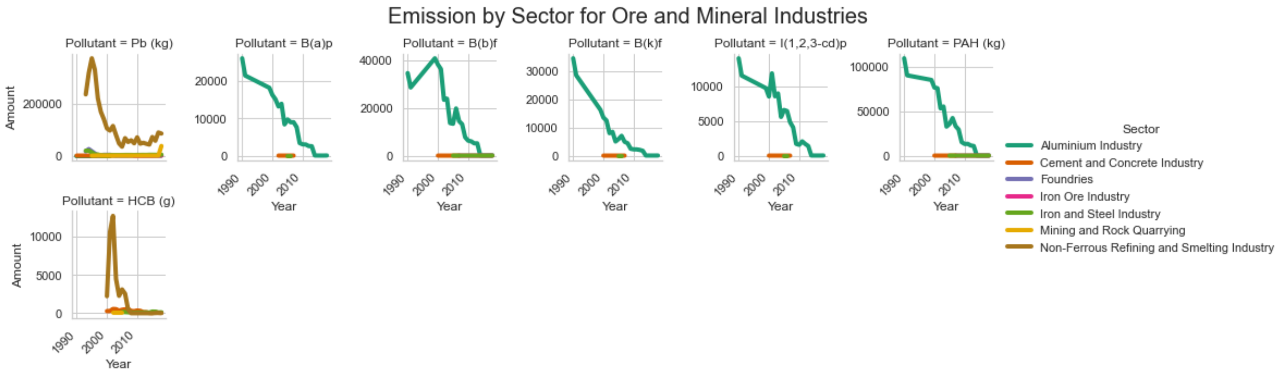

Figure 18. Sectors contributing to Ore and Mineral Industries pollution in Quebec. Disconnected line indicates missing data which are negligible.

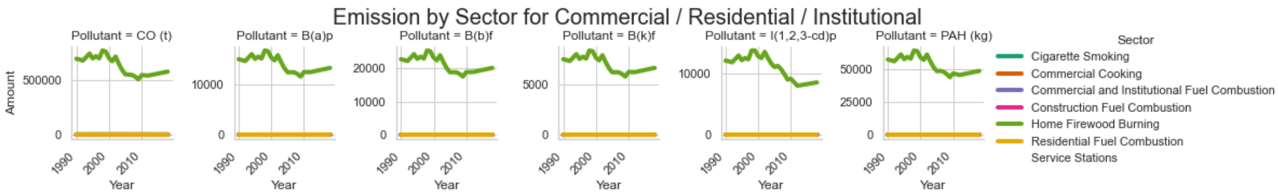

Figure 19. Sectors contributing to Commercial / Residential / Institutional pollution in Quebec.

As Quebec possesses nine out of ten primary aluminum plants in Canada, the result from Fig. 18 is not surprising. However, we can easily observe that the province has successfully reduced the PAH pollution over the period. In fact, Quebec has implemented a new program and continuously been reducing the PAH pollution significantly since the 1980s (Allaire,Barber, Friar, Roussel, 2012). There is no PAH emission from the Aluminum industry anymore at the current date.

On the other hand, the PAH pollutant emissions from *Home Firewood Burning* (Fig. 19) are showing slow increasing trends. One of the reasons is most likely to be related to the population growth in Quebec. By introducing more strict rules regarding the firewoods at home, the province should be able to adjust the amount.

Within *Ore and Mineral Industries*, *Non-Ferrous Refining and Smelting Industry* for primary metals such as nickel, lead, zinc, and copper are seen as the main causes of the Pb and HCB pollution (Fig. 18). There appear to be spikes for the amount of pollutants in early 2000 for HCB, and late 1990s for Pb emission. The possible cause could be a failure to execute proper procedures from some of the related plants as these sudden increases only lasted temporarily. Unfortunately, the data indicates a slow increasing trend of Pb towards the recent years. Since Pb air pollution can cause significant health concerns related to lead poisoning especially for young children (World Health Organization, 2019), more investigation is suggested to be conducted to cease the increasing trend.

Figure 17 also informs that there are two other sources that are causing the major pollution of CO, D/F, and HCB which are *Transportation and Mobile Equipment* and *Incineration and Waste*. The meaning of *Incineration and Waste* is self-implied; whereas, more insights about the source, *Transportation and Mobile Equipment* are shown at *Figure 20* where every sector of human activities demonstrates decrease in CO emission except for a bit of increase in *Off-road Gasoline/LPG/NG Vehicles and Equipment* in 2018.

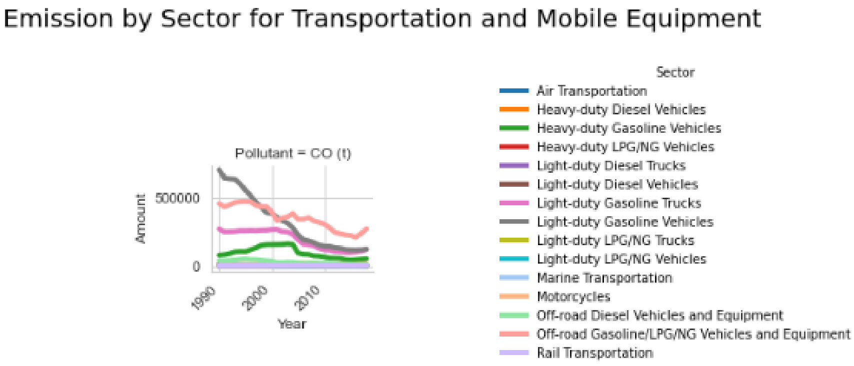

Figure 20. Sectors in Transportation and Mobile Equipment pollution

From the analysis, it is evident that Quebec's programs and campaigns to reduce the pollutant emissions are mostly successful. An implementation of more strict rules towards the usage of firewoods at home is suggested to bring down the PAH pollution levels. Inspections regarding the increase in Pb and *Off-road Gasoline/LPG/NG Vehicles* are recommended as well as they indicated an increasing trend towards the recent years.

Case Study: Manitoba

For Manitoba, we will be focusing on the following pollutants: TPM, PM_{10}, $PM_{2.5}$, NH_3, Cd, Hg, NO_X, VOC. These pollutants have shown an increase in emissions over the years, with the exception of Cadmium and Mercury. Cadmium and Mercury were included in this analysis due to its high volatility during the 1990s to late 2000s, as represented in Fig. 21.

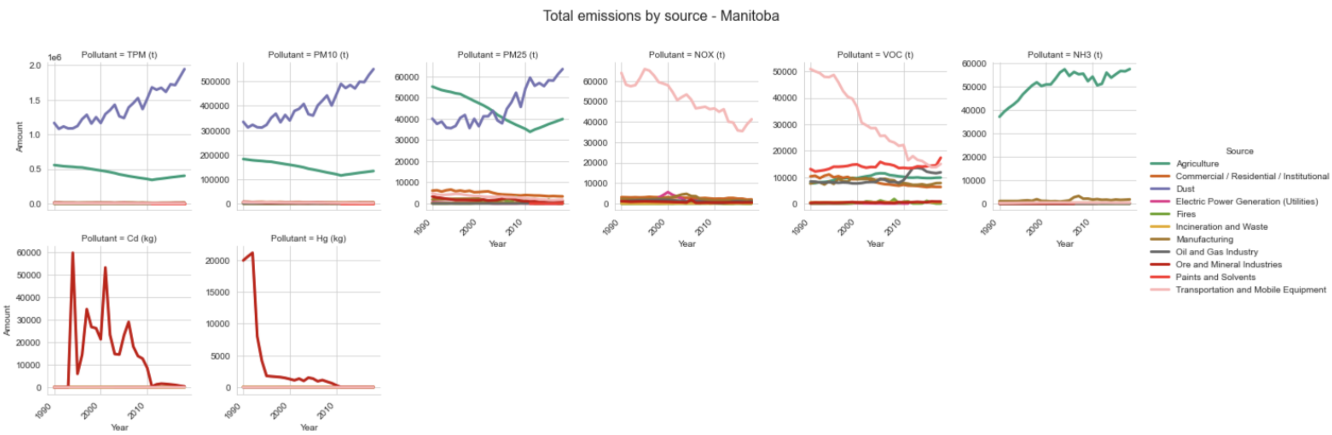

Figure 21. Sources contributing to key air pollutant emissions in Manitoba.

Dust sectors contributing to particulate matter emissions

One of the most concerning trends is the spike in TPM, PM_{10} and $PM_{2.5}$ from late 2000s to 2018 (Fig. 21). These changes come from a significant increase in *Dust*, generated from *Unpaved Roads* and *Construction Operations* (Fig. 22). The increase of emissions from *Unpaved Roads* can be accounted to Manitoba's rural landscape and lack of proper road infrastructure. Since Manitoba's economy is largely based on natural resources, massive plots of lands across Manitoba will have to remain untampered to make space for farming/agricultural activities and resource extraction.

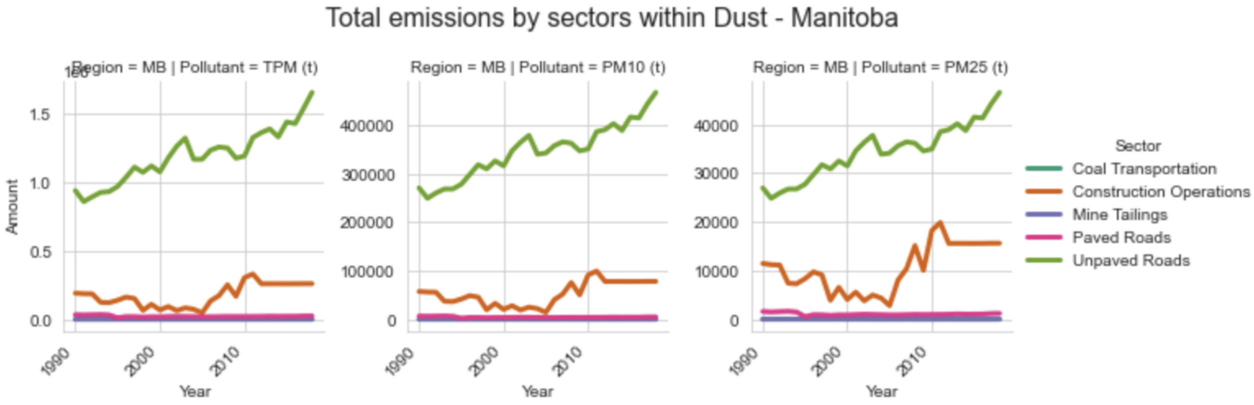

Figure 22. Sectors contributing to all PM emissions in Manitoba.

Construction Operations is a key industry in Manitoba as well, and a common contributor to the production of Particulate Matter and overall urban smog. Based on the data, TPM, PM_{10} and $PM_{2.5}$ will continue to show an upward trajectory as the years progress.

Agriculture sectors contributing to NH_3 emissions

As we shift our focus to NH_3, we notice significant increases since 1990, with little to no divots in its upwards trajectory, predominantly in *Crop Production* (Fig. 23). These high emissions are primarily driven by *Animal Production* and *Crop Production* as part of the *Agriculture* industry. Due to Manitoba's agricultural needs, chemically-heavy products such as Nitrogen fertilizer are used in agricultural processes that excretes high levels of NH_3.

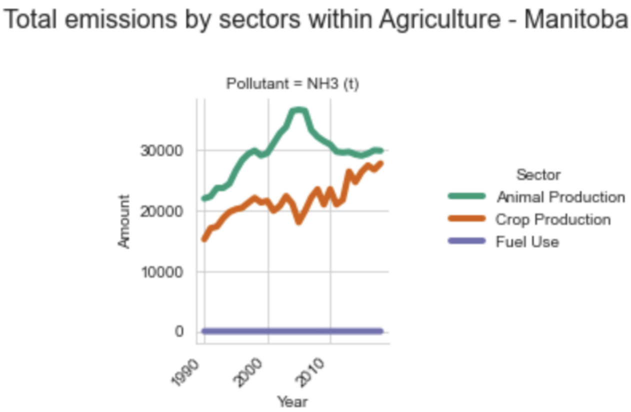

Figure 23. Sectors contributing to all MH3 emissions in Manitoba.

Transportation and Mobile Equipment sectors contributing to VOC and NO_X emissions

Looking at VOC and NO_X, there has been a significant reduction on these emissions since 1990, essentially plummeting to a new low in the mid 2010s. However, going past the mid 2010s, there has been a small and steady increase in these pollutants, specifically in a few sub sectors of *Transportation and Mobile Equipment* (Fig. 24), which begs the question, "why?"

For NO_X, there are rising emissions in three sub sectors: *Air Transportation*, *Heavy-duty Diesel Vehicles*, and *Off-road Diesel Vehicles and Equipment*. For VOC, there are rising emissions in one sub sector: *Off-road Gasoline/LPG/NG Vehicles and Equipment*.

Typically, any sector that is fuel based, there will be a decrease in fuel related pollutants due to a high demand in electrical and renewable energy. Provincial and municipal governments play a role in this decrease as well, as they conventionally incentivize their citizens to make the transition to alternative energies.

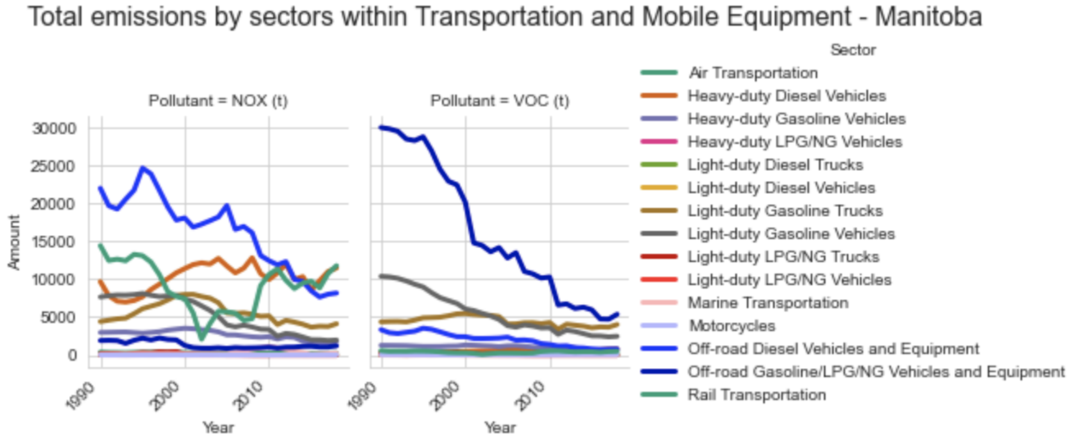

Figure 24. Sectors contributing to all NO_X and VOC emissions in Manitoba.

However, a possible explanation for the steady increase in NO_X and VOC emissions in *Transportation and Mobile Equipment* is the recent change in Manitoba's provincial government from NDP to Progressive Conservative in 2016. Different political parties tend to prioritize different industries and sectors of interest.

Ore and Mineral Industries sectors contributing to Cd and Hg emissions

Also notable are Cd and Hg - we see alarming spikes in emissions from 1990 to mid 2000s, before suddenly dropping off in recent years (Fig. 25). Taking into consideration the emissions levels of other provinces (Fig. 4), Manitoba was a major contributor to Canada's Cd and Hg discharges. These emissions stemmed from Manitoba's *Non-Ferrous Refining and Smelting Industry* (within the *Ore and Mineral Industries*), and its lack of waste management infrastructure.

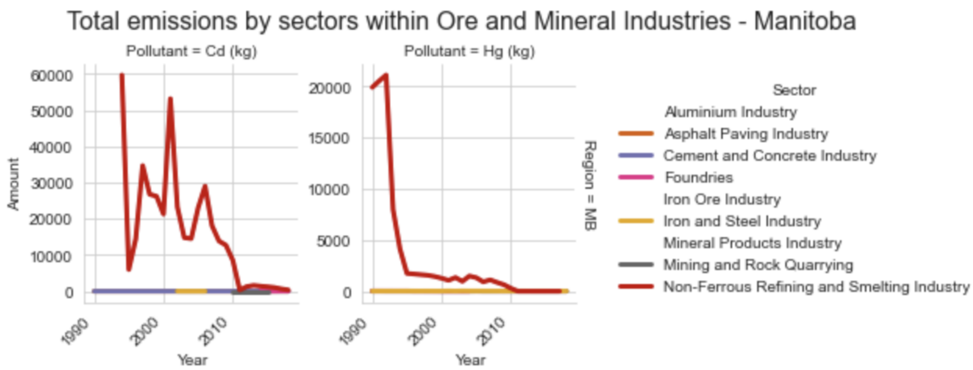

Figure 25. Sectors contributing to all Cd and Hg emissions in Manitoba.

Conclusion

Overall, by examining our results, we were able to gain valuable insight as to the areas in which air pollutant emissions can be improved. Specifically, we were able to verify that the most pollutant heavy industries vary depending on the region, and the prominent human activities associated within those areas. By applying exploratory data analysis and visualization techniques, our data revealed that on a national scale Canada has reduced emissions for most air pollutants from 1990 to 2018. Some of these pollutants include SO_X, NO_X, VOC, and CO. However, despite Canada's efforts, our data still highlights alarming increases in certain pollutants, namely TPM, PM_{10} (types of Particulate Matter), and NH_3.

Through our analysis, we discovered that the top regional contributors to air pollutant emissions were Alberta, Saskatchewan, Manitoba, Ontario, and Quebec. The most frequent pollutant we discovered in these regions was particulate matter, which showed increasing trends in Alberta, Saskatchewan, Manitoba, and Ontario. All four regions pinpointed Dust and Agriculture sectors as the top contributors to particulate matter emissions. In addition, both Saskatchewan and Alberta proved to be top polluters for NH_3 and VOC, whereas Quebec was a major contributor in PAH associated pollutants. The data also portrays Alberta as the most pollutant-heavy province within our timeframe, showing increasing emissions for six pollutants.

Our data overall illustrates the progress Canada has made in reducing emissions for most air pollutants since 1990. Our findings also emphasize the need for additional measures, focused on reducing the emissions of Particulate Matter and NH_3. The information we gathered can be used to draw attention to the matter of increasing air pollutants, while employing stricter protocols within the regions and industries with the most emissions. Doing so would not only help reduce emissions, but also minimize health and environmental complications related to elevated pollution levels.

Appendix

References

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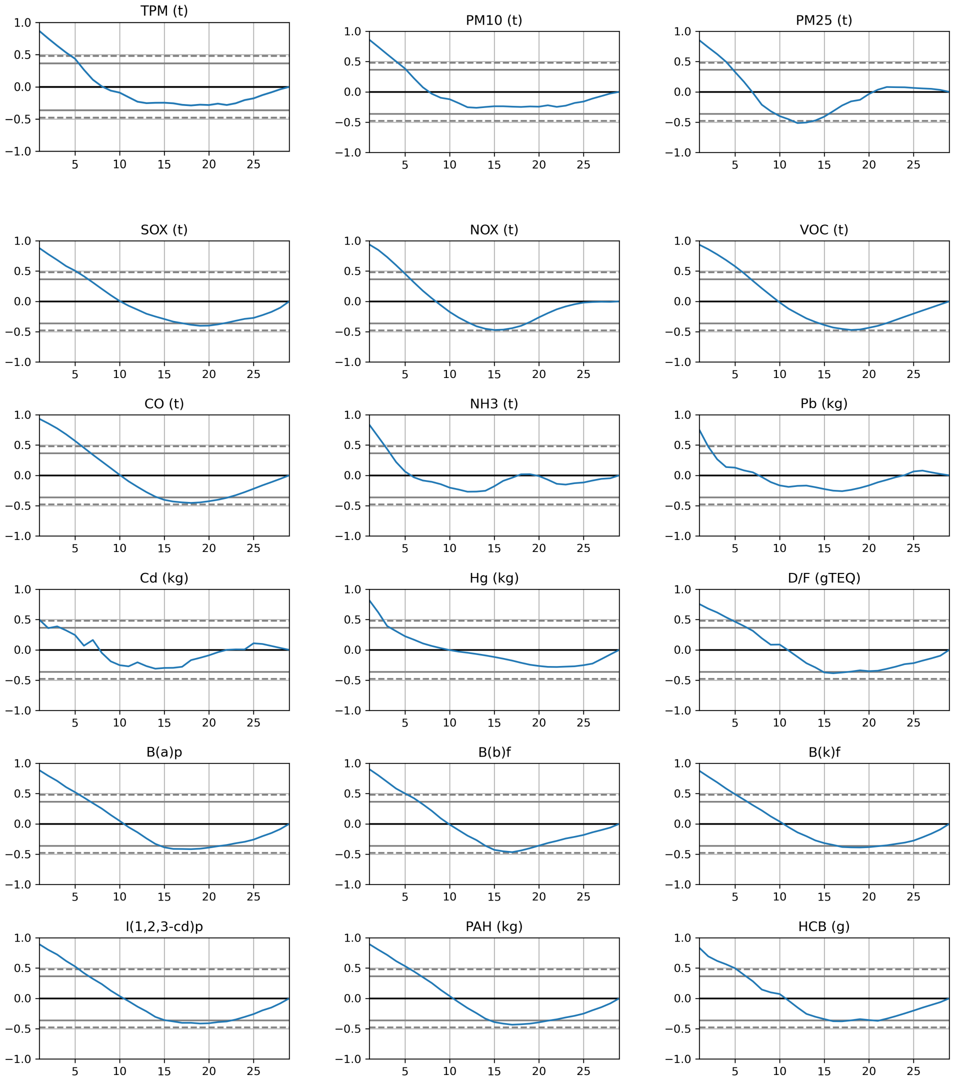
Supplementary tables

POLLUTANT	TYPE	NAMES	UNITS
Hg	Heavy Metal	Mercury (elemental, inorganic)	kg
Cd	Heavy Metal	Cadmium (inorganic/respirable/soluble)	kg
Pb	Heavy Metal	Lead (all forms except alkyl)	kg
B(a)p	PAH	Benzo(a)pyrene	kg
B(b)f	PAH	Benzo(b)fluoranthene	kg
B(k)f	PAH	Benzo(k)fluoranthene	kg
I(1,2,3-cd)p	PAH	Indeno(1,2,3-CD)pyrene	kg
HCB	POP	Hexachlorobenzene	grams
D/F	POP	Dioxins and furans	g TEQ(ET)
CO	CAC	Carbon monoxide	tonnes
VOC	CAC	Volatile Organic Compounds	tonnes
SOx	CAC	Sulphur oxides	tonnes
NOx	CAC	Nitrogen oxides	tonnes
TPM	CAC	Total Particulate Matter	tonnes
PM_{10}	CAC	Particulate Matter - 10 Microns or less	tonnes
$PM_{2.5}$	CAC	Particulate Matter - 2.5 Microns or less	tonnes
NH_3	CAC	Ammonia	tonnes

Supplementary Tbl 1. Government of Canada Open Data (2020).

Supplementary figures



Supplementary Figure 1. Autocorrelation plots per pollutant (sum total of all regions and all sources, per year).